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Meteoritic debris from the Southern California desert

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Abstract—During an examination of magnetic material from California desert sand, two meteoritic particles were found. One was a typical cosmic spherule consisting of nickel–iron with an iron-oxide shell; that is, it was an iron oxide spherule with a metallic inclusion or nucleus. The other contained 85 per cent magnesium–iron silicate and 15 per cent nickel–iron. Both particles were analysed with an electron microprobe, and their meteoritic character wasnoted.

INTRODUCTION

During September 1961, one of us (R. G.) collected material for this investigation in the Southern California desert at Lat. 32° 55′ N and Long. 115° 46′ W. Magnetic minerals were obtained by dragging a magnet in the soil, mainly sand and gravel. A radar tube magnet with a pole gap of 16 mm and a field strength of 4500 gauss was used. The pole pieces reached about 75 mm below the surface, and magnetic particles were thus extracted from approximately $\frac{1}{10}$ cubic meter of soil. After sieving, about 100 g material finer than 1 mm remained. This was examined at $10\times$ magnification, and 32 black spherules 30 to 300 μ in diameter were found and retained for analysis. (Fig. 1.) All were similar in appearance, to so called cosmic spherules described by several authors (e.g., CROZIER, 1961; PETTERSSON and FREDRIKSSON, 1958). Some spherules smaller than 30 or even 50 μ may have been overlooked, as these are not easily perceived.

To analyse the interior of the 32 spherules, they were mounted in epoxy resin, were ground down and were polished repeatedly. Thirty of them seemed to consist entirely of iron oxide; this was confirmed by analysis at several levels in the spherules (Ni $<$ 0·2 per cent). But, two particles revealed metallic inclusions and therefore were analysed in detail with interesting results.

EXPERIMENTAL RESULTS AND DISCUSSION

One of the two particles given special analysis was an iron–oxide spherule 120 microns in diameter, with a metallic nucleus. (Fig. 2.) Detail of its composition, in percentage of its total weight, was as follows:

Metal, 6%;	Ni, 68;	Fe, 31;	Co, 1;
Oxide, 94%;	$\sim$0.2;	72 $\pm$ 1;	

Ni:Fe ratio for the total, 5:100

This spherule is similar in composition to the cosmic spherules described by CASTAING and FREDRIKSSON (1958). However, no spherules of this type from terrigenous deposits have to our knowledge been analysed before and thus proved to be meteoritic.

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The second particle with a metallic inclusion was drop-shaped, with the longest axis about 300 μ. (Figs. 2, 3.) When first cut, it appeared to be only silicate and was not analysed. But a cut through the center exposed a metallic inclusion (Fig. 3); and electron microprobe analysis gave the results indicated in the following detail of its content, in percentage of total weight:

Metal, 15 per cent of which about 2 per cent was dispersed in small grains in the silicate:

Fe, 62;	Ni, 37;	Co, 1·1;	
Silicate, 85%	SiO_2, 41;	MgO, 38;	FeO, 20;

and 1% (Al_2O_3, + CaO, + MnO).

The silicate has composition close to an olivine with about 85 mol per cent forsterite.

For the silicate part, two well analysed olivines $(Mg, Fe)_2SiO_4$*, were used as standards. For the metallic part, use was made of pure iron, nickel, and cobalt. The iron content of the oxide was measured against magnetite (Fe_3O_4). The X-ray intensities were corrected for background, detector dead time, varying mass absorption, and fluorescence (i.e., iron Kα excited by nickel Kα radiation).

The chemical composition of both silicate and metal is consistent with a meteoritic origin. The structure of the silicate is similar to that of so called radiating pyroxene chondrules commonly found in chondritic meteorites.

A diffraction pattern of the silicate part of the spherule described above (Figs. 3 and 4) was obtained from the last remains of the spherules examined (a thin section 120 × 100 × 30 μ, Fig. 5) reproducing a photograph made with a Chesley camera (CHESLEY, 1947) 100 μ capillary; FeKα radiation. Only olivine was identified, as the following data show:

d (A)	hkl (olivine)
4·25	(110)
3·80	(101)
2·80	(130)
2·52	(131)
2·36	(041)
2·33	(210)
2·28	(122)

The spherule seems to have formed by the rapid cooling of a melted droplet, presumably originating on the surface of a larger meteoritic body during its passage through the atmosphere, just as we believe that most of the usual cosmic spherules are formed. (FREDRIKSSON, 1959; FREDRIKSSON and MARTIN; in press.)

Similar silicate particles from various sources have been described by several authors. MURRAY and RENARD (1891) assumed this type of spheres to be chondrules from chondrites broken up in the atmosphere. However, it has been difficult to prove the origin of this type of particles. Even with microanalysis

* Metallic magnesium and silicon cannot easily be used as standards because of the shift of MgKα and SiKα due to different valence state (See FREDRIKSSON *Electron Microprobe analysis of mineral phases in the Enstatite Chondrites St. Marks and Indarch* (To be submitted to *Geochim. et Cosmochim. Acta*).

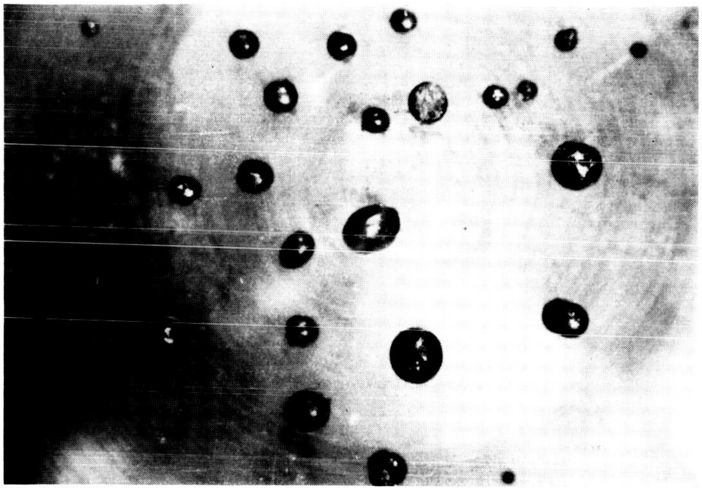

Fig. 1. Magnetic spherules from the Southern California desert. The largest one has a diameter of about 300 μ.

Fig. 2. Cosmic spherule. White = nickel–iron (68% Ni). Light grey = iron oxide. Diameter of spherule, 120 μ.

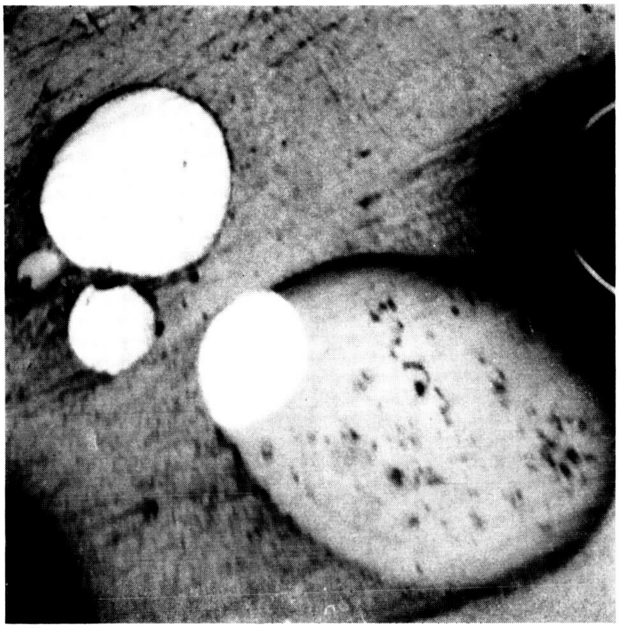

Fig. 3. Polished section through center of silicate (dark grey) spherule, with nickel-iron (37% Ni) inclusion, white. Longer axis = 300 μ. The three smaller spherules consist of iron oxide with a composition close to Fe_3O_4.

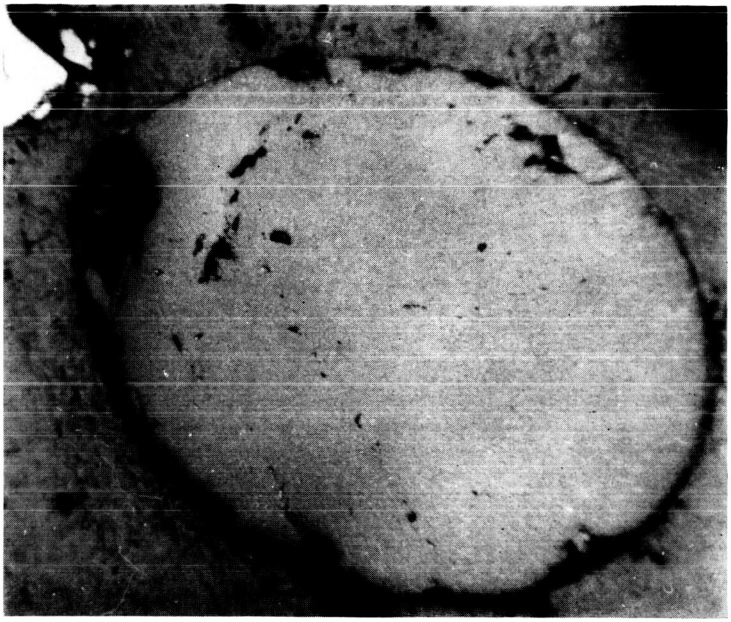

Fig. 4. Polished section of same silicate spherule as in Fig. 3, but 30 μ farther down. The small white spots are nickel iron. The silicate crystals, mainly olivine, radiate from the site of the nickel–iron nucleus, the last residue of which was lost during polishing. (See black hole at the upper left).

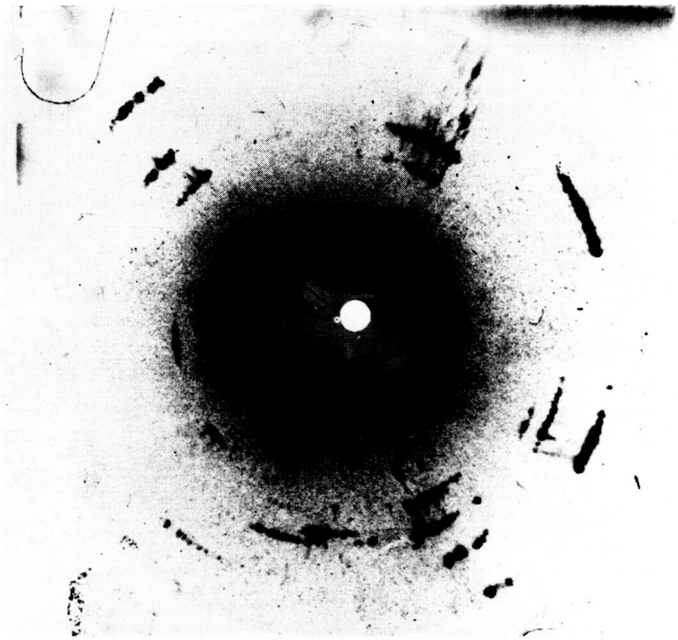

Fig. 5. Diffraction pattern of silicate part of the spherule shown in Figs. 3 and 4. The elongated spots indicate preferred orientation of the crystals. Only olivine was identified (Table 3).

the evidence may not be conclusive unless nickel-iron inclusions can be found. This, as well as the fact that only one of the 32 spherules found was an ordinary cosmic spherule, emphasizes the need of careful examination of any particles found on the earth or in the atmosphere during search for extra-terrestrial matter. The 30 solid iron-oxide spherules found on the occasion of the present study are probably artificial contamination from the nearby San Diego area and not of volcanic origin, since the volcanic spherules (FREDRIKSSON and MARTIN, 1963) usually are hollow and contain silicates.

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